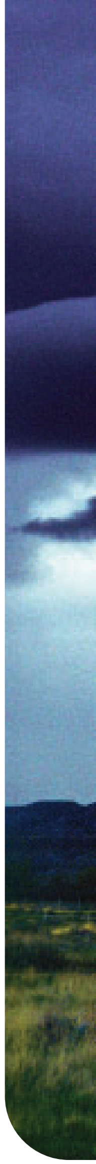
chapter

14 The Senses

In this chapter

David Hume, the great Scottish philosopher, once concluded that humans are nothing more than the sum of their experiences. Elders in Aboriginal societies are revered because of their experiences. Our experiences, or what some philosophers call reality, exist because of a sensory nervous system. Environmental stimuli such as the flash of lightning (**Figure 1**), the sound of thunder, the chill of a cold day, and the smells of food are relayed to the brain by sensory neurons.

As you learned in the previous chapter, sensory neurons supply the central nervous system with information about the external environment and our internal environment. Whether it is information gathered by the sensory receptors of the eye or from those of the ear, it is carried to the brain along neurons as electrochemical impulses. Different parts of the brain process auditory information and visual information. How sensory information is perceived depends on which part of the brain receives the impulse. For example, if a visual sensory neuron were instead routed to the processing site for auditory information, you might hear lightning!



STARTING Points

Answer these questions as best you can with your current knowledge. Then, using the concepts and skills you have learned, you will revise your answers at the end of the chapter.

1. Imagine if neurons carrying sensory information about sound were surgically moved from the sound interpreting area in the temporal lobe to the vision interpreting area in the occipital lobe.
   (a) How would the brain interpret a loud sound?
   (b) Would moving the nerve ending to another part of the visual area of the occipital lobe cause a different interpretation of the stimulus? Explain why or why not.
2. When you first walk into a kitchen where fish is cooking, the smell is strong and distinctive, yet after a few minutes the smell disappears.
   (a) Why does the smell seem to disappear?
   (b) What advantage is gained from having the smell disappear?
3. Predict which of the following areas of the body are most sensitive to touch by placing them in order. Provide reasons for the order you have chosen.
   - back of the neck
   - lips
   - face
   - fingertips
   - palms of hand
   - shoulder

Figure 1
The central nervous system processes environmental stimuli.

Exploration — Detecting Temperature Changes

Heat and cold receptors, rather than detecting specific temperatures as does a thermostat, are adapted to signal *changes* in environmental temperatures.

Materials: 3 bowls or large beakers, warm water, room-temperature water, cold water

- Fill three bowls or large beakers with water—one with warm, one with room-temperature, and one with cold water.
- Place your right hand in the cold water and your left hand in the warm water (**Figure 2**). Allow your hands to adjust to the temperature and then transfer both hands to the bowl that contains room-temperature water.
  (a) Describe what happens.
  (b) Explain why you might feel a chill when you step out of a warm shower even though room temperature is comfortable.
  (c) Explain the following observations: When a frog is placed in a beaker of water above 40 °C, the frog will leap out immediately. When the frog is placed in room-temperature water and the temperature is slowly elevated, the frog will remain in the beaker.

Figure 2

14.1 Sensory Information

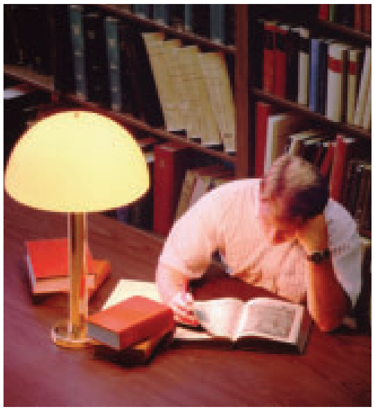


Figure 1
In order for us to see, visual receptors in the eye must be stimulated by light.

Sensory neurons supply the central nervous system with information about the external environment and the quality of our internal environment. Light-sensitive receptors within the retina of the eye are stimulated by light, not sound (**Figure 1**). A group of specialized temperature receptors in the skin identify cold, while other ones identify heat. Specialized chemoreceptors in the carotid artery provide the central nervous system with information about blood carbon dioxide and oxygen levels. Special osmoregulators in the hypothalamus monitor water concentration in the blood, and highly modified stretch receptors monitor blood pressure in arteries. How do different receptors respond to different stimuli? How are different stimuli converted into electrochemical events? How do you identify the intensity of different stimuli? How does the brain interpret stimuli?

A stimulus is a form of energy. Sensory receptors convert one source of energy into another. For example, taste receptors in your tongue convert chemical energy into a nerve action potential, a form of electrical energy. Light receptors in the eye convert light energy into electrical energy. Balance receptors of the inner ear convert gravitational energy and mechanical energy into electrical energy.

As you learned in Section 13.1, sensory receptors are highly modified dendrites of sensory neurons. Often, different sensory receptors and connective tissues are grouped within specialized sensory organs, such as the eye or ear. This grouping of different receptors often amplifies the energy of the stimulus to ensure that the stimulus reaches threshold levels. **Table 1** lists different types of sensory receptors found within the body, classified by the type of stimulus to which they respond.

Table 1 The Body's Sensory Receptors

Receptor Type	Stimulus	Information provided
taste	chemical	presence of specific chemicals (identified by taste buds)
smell	chemical	presence of chemicals (detected by olfactory cells)
pressure	mechanical	movement of the skin or changes in the body surface
proprioceptor	mechanical	movement of the limbs
balance	mechanical	body movement
audio	sound	sound waves
visual	light	changes in light intensity, movement, and colour
thermoreceptor	temperature changes	flow of heat

A network of touch, heat, cold, pressure, and pain receptors are found throughout the skin (**Figure 2**, next page). Pain receptors have naked dendrites in the epidermis. Pain receptors are extremely important because the sensation of pain makes you move away from whatever is causing the stimulus, which protects you from harm. A simple experiment indicates that sensations occur in the brain and not the receptor itself. This phenomenon is supported by brain-mapping experiments. When the neurotransmitter released by the sensory neuron is blocked, the sensation stops. Thus the brain registers and interprets the sensation. When the sensory region of the cerebral cortex is excited by mild electrical shock at the appropriate spot, the sensation returns even in the absence of the stimulus.

DID YOU KNOW?

Seeing Stars

Occasionally a sensory receptor can be activated by stimuli that it was not designed to detect. Boxers who receive a blow to the eye often see stars. The pressure of the blow stimulates the visual receptors at the back of the eye, and the blow is interpreted as light. Similarly, a blow near the temporal lobe can often be interpreted as a bell ringing.

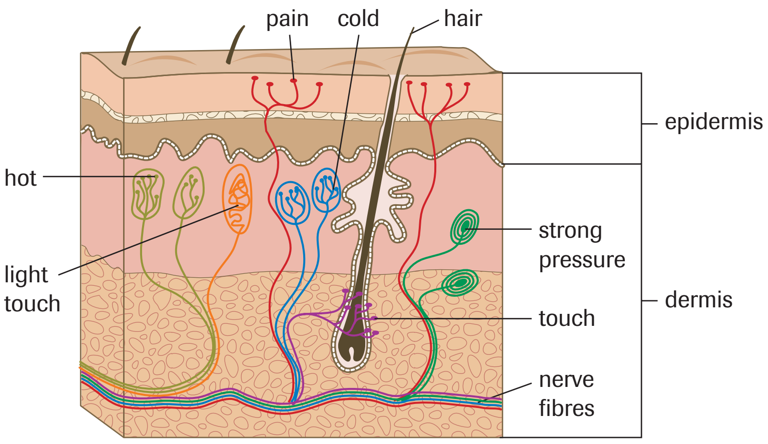


Figure 2 Each sensory receptor in the skin has dendrites modified in a different way.

Despite an incredible collection of specialized sensory receptors, much of your environment remains undetected. What you detect are stimuli relevant to your survival. For example, consider the stimuli from the electromagnetic spectrum. You experience no sensation from radio waves, or from infrared or ultraviolet wavelengths. Humans can only detect light of wavelengths between 350 nm and 800 nm. Your range of hearing, compared with that of many other species, is also limited.

Thermoreceptors do not act as thermometers, which detect specific temperatures. Hot and cold receptors are adapted to signal changes in environmental temperatures. Most animals can tolerate a wide range of temperatures, but are often harmed by rapid temperature changes. For example, a rapid change in temperature of 4 °C will kill some fish. Humans have also died from an unexpected plunge in very cold or very hot water. This principle was introduced in the Exploration at the start of Chapter 14 with the description of the "hot frog" experiment. If a frog is placed in a beaker of water above 40 °C, the frog will leap out immediately. However, if the frog is placed in room-temperature water, and the temperature is slowly elevated, it will remain in the beaker. The frog's thermoreceptors have had time to adjust.

sensory adaptation occurs once you have adjusted to a change in the environment; sensory receptors become less sensitive when stimulated repeatedly

Sensory adaptation occurs once the receptor becomes accustomed to the stimulus. The neuron ceases to fire even though the stimulus is still present. The adaptation seems to indicate that the new environmental condition is not dangerous. The same principle of adaptation can be applied to touch receptors in the skin. Generally, the receptors are only stimulated when clothes are put on or taken off. Sensory information assuring you that your clothes are still on your body is usually not required.

Taste and Smell

Taste receptors allow you to differentiate between things that are edible and things that are inedible. Taste receptors are found in different locations in different species. For example, octopuses have taste receptors on their tentacles. In humans, taste receptors are concentrated in the taste buds on the tongue (**Figure 3**). Specific chemicals dissolve on the tongue and stimulate receptors in the taste buds. There are five main types of taste: sweet, sour, salt, bitter, and savoury (also called umami). Each is associated with molecular shapes or charges. For example, salty taste is associated with the positive sodium ion, and savoury taste is associated with salts of glutamic acid. For example, table salt (sodium chloride) is a common salty food enhancer in foods such as potato chips and canned foods, and monosodium glutamate is a common savoury food enhancer in Asian cuisine and processed foods. A taste bud contains 1 to 200 cells. Each cell can

Figure 3 Dissolved chemicals enter the taste pore where they are detected by receptor cells. There are more than 10 000 taste buds in a human mouth.

respond to chemicals responsible for all the taste types, but it tends to be more responsive to one particular chemical. When you bite into an orange slice, the brain processes information from all the different cells and perceives a complex flavour.

Experience tells you that your sense of taste and smell (olfaction) work together. Have you ever noticed that when you have a cold, your ability to taste food is reduced? Clogged nasal passages reduce the effectiveness of olfactory cells (located in the nasal cavity). Since you use both types of receptors to experience food, the diminished taste you experience is actually the result of your reduced capacity to smell the food. The main difference between taste and smell is that smell detects airborne chemicals and taste detects dissolved chemicals.

DID YOU KNOW ?

Taste + Smell + Irritation = Flavour

When you describe how a food "tastes" you are really describing its flavour, which is actually the combination of its taste, smell, and chemical irritation. Chemical irritants, such as the burn of chili peppers or the cool of menthol, add to the way things feel in your mouth.

INVESTIGATION 14.1 *Introduction*

Mapping Sensory Receptors

Sensory receptors are specialized structures designed to respond to specific stimuli from the internal or external environment. Receptors convert information about changing environments to electrochemical impulses, which are transmitted to the central nervous system. In this investigation you will map the position of several sensory receptors in the skin.

Report Checklist

○ Purpose	● Design	● Analysis
● Problem	○ Materials	● Evaluation
● Hypothesis	○ Procedure	● Synthesis
● Prediction	● Evidence	

To perform this investigation, turn to page 462.

SUMMARY *Sensory Information*

- Sensory receptors are highly modified dendrites of sensory neurons that detect information about the external or internal environment.
- Sensory receptors convert one form of energy into another. For example, the eye converts light energy into an electrochemical impulse.
- Taste receptors detect dissolved chemicals; olfactory receptors detect airborne chemicals. Taste and olfactory receptors act together to create the perception of taste.

Section 14.1 Questions

1. Identify a sensory receptor for each of the following stimuli: chemical energy, mechanical energy, heat, light energy, and sound energy.
2. Do sensory receptors identify all environmental stimuli? Give examples to back up your answer.
3. Explain the concept of sensory adaptation by using examples of olfactory stimuli and auditory stimuli.
4. Explain why you are less able to taste food when you have a cold.

The Structure of the Eye 14.2

One of the primary ways humans gather information about their environment is through the visual information supplied by the sensory receptors in the eye. The structure of the eye allows for sensory information to be gathered and transmitted to the brain efficiently. The eye comprises three separate layers: the sclera, the choroid layer, and the retina (**Figure 1**). The **sclera** is the outermost layer of the eye. Essentially a protective layer, the white fibrous sclera maintains the eye's shape. The front of the sclera is the clear, bulging **cornea**, which acts as the window to the eye by bending light toward the pupil. Like all tissues, the cornea requires oxygen and nutrients. However, the cornea is not supplied with blood vessels, which would cloud the transparent cornea. Most of the oxygen is absorbed from gases dissolved in tears. Nutrients are supplied by the **aqueous humour**, a transparent fluid in a chamber behind the cornea.

sclera outer covering of the eye that supports and protects the eye's inner layers; usually referred to as the white of the eye

cornea transparent part of the sclera that protects the eye and refracts light toward the pupil of the eye

aqueous humour watery liquid that protects the lens of the eye and supplies the cornea with nutrients

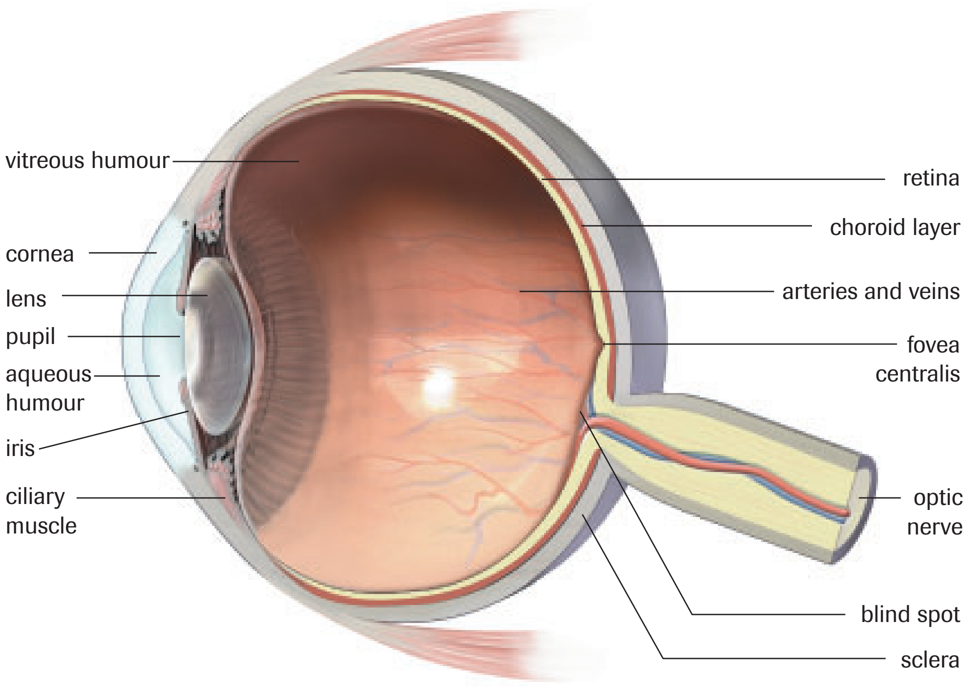


Figure 1
Simplified diagram of the human eye

EXTENSION

Focusing Light on the Retina
Listen to this description of the structures of the eye that actively and passively refract light so that it can be focused with high resolution on the surface of the retina.

www.science.nelson.com GO

The middle layer of the eye is called the **choroid layer**. Toward the front of the choroid layer is the **iris**. The iris is composed of a thin circular muscle that acts as a diaphragm, controlling the size of the pupil, the opening formed by the iris that allows light into the eye. The lens, which focuses the image on the retina, is found in the area immediately behind the iris. Ciliary muscles, attached to ligaments suspended from the dorsal and ventral ends of the lens, alter the shape of the lens. A large chamber behind the lens, called the vitreous humour, contains a cloudy, jellylike material that maintains the shape of the eyeball and permits light transmission to the retina.

choroid layer middle layer of tissue in the eye that contains blood vessels that nourish the retina

iris opaque disk of tissue surrounding the pupil that regulates amount of light entering the eye

retina innermost layer of tissue at the back of the eye containing photoreceptors

rods photoreceptors that operate in dim light to detect light in black and white

cones photoreceptors that operate in bright light to identify colour

The innermost layer of the eye is the **retina**, which comprises four different layers of cells: pigmented epithelium, light-sensitive cells, bipolar cells, and cells of the optic nerve. The pigmented epithelium is positioned between the choroid layer and the light-sensitive cells. Pigmented granules in this layer prevent light that has entered the eye from scattering. There are two different types of light-sensitive cells: the **rods** and the **cones** (**Figure 2**). The rods respond to low-intensity light; the cones, which require high-intensity light, identify colour. Both rods and cones act as the sensory receptors. Once excited, the nerve message is passed from the rods and cones to the bipolar cells, which, in turn, relay the message to the cells of the optic nerve. The optic nerve carries the impulse to the central nervous system (**Figure 3**).

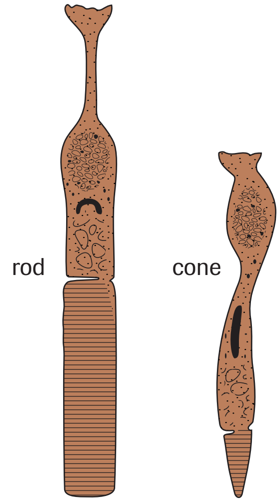


Figure 2
In humans, there are about 18 times as many rods (orange) as cones (red) in the retina.

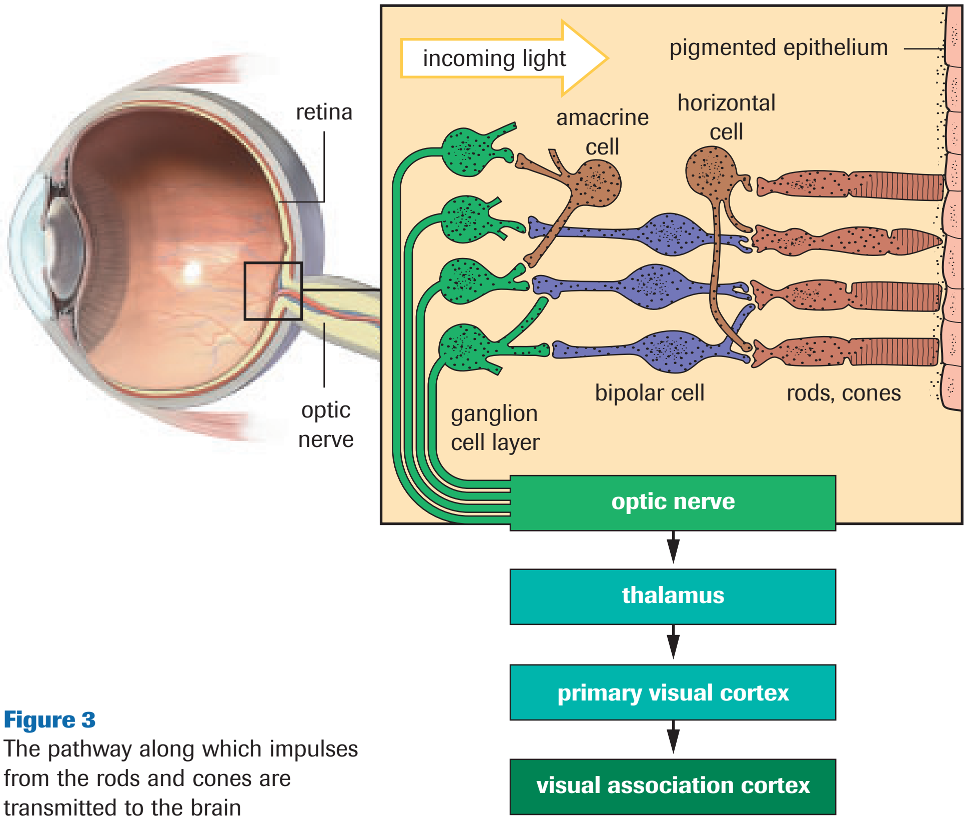


Figure 3
The pathway along which impulses from the rods and cones are transmitted to the brain

Rods and cones are unevenly distributed on the retina. In the centre of the retina is a tiny depression referred to as the **fovea centralis**. The most sensitive area of the eye, it contains cones packed very close together. When you look at an object, most of the light rays fall on the fovea centralis. Rods surround the fovea, which could explain why you may see an object from the periphery of your visual field without identifying its colour. There are no rods or cones in the area in which the optic nerve comes in contact with the retina. Because of this absence of photosensitive cells, this area is appropriately called the blind spot. **Table 1** summarizes the different parts of the eye.

fovea centralis area at centre of retina where cones are most dense and vision is sharpest

Table 1 Parts of the Eye

Structure	Function
sclera	• supports and protects delicate photocells
cornea	• refracts light toward the pupil
aqueous humour	• supplies cornea with nutrients and refracts light
choroid layer	• contains blood vessels that nourish the retina
iris	• regulates the amount of light entering the eye
vitreous humour	• maintains the shape of the eyeball and permits light transmission to the retina
lens	• focuses the image on the retina
pupil	• the opening in the iris that allows light into the eye
retina	• contains rods used for viewing in dim light and cones used for identifying colour
fovea centralis	• most light-sensitive area of the retina • contains only cones
blind spot	• where the optic nerve attaches to the retina

CAREER CONNECTION

Optometrist
Does the biology of the eye fascinate you? Understanding how the complex parts of the eye work together to produce vision is essential for treating eye and health-related disorders, such as glaucoma. Optometrists are eye specialists who conduct examinations, diagnose disease, evaluate eye structure, and prescribe drugs, eyeglasses and contact lenses. Find out more about this career choice.

www.science.nelson.com GO

Practice

1. List the three layers of the eye and describe the function of each layer.
2. Compare rods and cones in terms of location, structure, and function.

EXTENSION

Simulation—Principal Features of the Eye
In this animation, you will observe the structure of the human eye while listening and reading about the function of each structure. At the end of the animation, you will complete an interactive quiz to test your understanding.

www.science.nelson.com GO

INVESTIGATION 14.2 *Introduction*

Eye Dissection

The eyes of most mammals have very similar anatomy. Dissection of a cow eye can therefore help you better understand the structures of the human eye. In this investigation, you will dissect a cow eye and describe the structures you observe.

To perform this investigation, turn to page 463.

Report Checklist

- ○ Purpose
- ● Problem
- ○ Hypothesis
- ○ Prediction
- ● Design
- ○ Materials
- ○ Procedure
- ● Evidence
- ● Analysis
- ○ Evaluation
- ○ Synthesis

Chemistry of Vision

An estimated 160 million rods surround the colour-sensitive cones in the centre of the retina. The rods contain a light-sensitive pigment called **rhodopsin**, or "visual purple." The cones contain similar pigments, but they are less sensitive to light. Rhodopsin is composed of a form of vitamin A and a large protein molecule called opsin. When a single photon, the smallest unit of light, strikes a rhodopsin molecule, it divides into

rhodopsin the pigment found in the rods of the eye

two components: retinene, the pigment portion, and opsin, the protein portion. This division alters the cell membrane of the rods and produces an action potential. Neurotransmitters are released from the end plates of the rods, and the nerve message is conducted across synapses to the bipolar cells and to a neuron of the optic nerve. For the rods to continue to work, rhodopsin levels must be maintained. A long-term vitamin A deficiency can permanently damage the rods.

The extreme sensitivity of rhodopsin to light creates a problem. In bright light, rhodopsin breaks down faster than it can be restored. The opsins used for colour vision are much less sensitive to light and, therefore, operate best with greater light intensity. Since only the rods are active during periods of limited light intensity, images appear as shades of grey. Not surprisingly, the rods are most effective at dusk and dawn.

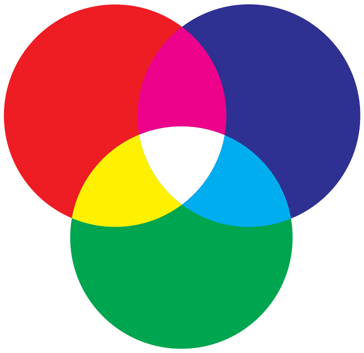


Figure 4
The three primary colours for source light are red, blue, and green. Each cone is sensitive to one of these three colours.

Colour Perception

The cones are responsible for colour vision. Each cone is sensitive to one of the three primary colours of source light: red, blue, and green. (Do not confuse the primary colours of source light with the primary colours of reflected light: magenta, cyan, and yellow.) When combinations of cones are stimulated by incoming light, the brain perceives different colours (**Figure 4**). For example, yellow is perceived when cones sensitive to both green and red wavelengths are stimulated. Purple is perceived when cones sensitive to both red and blue wavelengths are stimulated. Cyan (blue-green) is perceived when cones sensitive to blue and green wavelengths are stimulated. White is perceived when cones sensitive to all three wavelengths are stimulated. The three types of cones firing in different combinations allow humans to see millions of different shades of colour.

Colour blindness occurs when one or more types of cones are defective. The most common type of colour blindness, red-green colour blindness, occurs when the cones containing the red-sensitive pigment fail to work properly. The defect is genetic and more common in males than females.

DID YOU KNOW?

Seeing Ultraviolet Light
The lens of the eye is not clear. A slight yellow coloration blocks out rays from the ultraviolet end of the electromagnetic spectrum. As you age, your lenses become thicker and more yellow, making you less able to see wavelengths from the ultraviolet end of the spectrum.

Afterimages

Have you ever noticed a trailing blue or green line that stays in your vision after you look into a camera flash? What you see is an afterimage. There are two different types of afterimages: positive and negative. The positive afterimage occurs after you look into a bright light and then close your eyes. The image of the light can still be seen even though your eyes are closed. The more dramatic negative afterimage occurs when the eye is exposed to bright coloured light for an extended period of time.

mini *Investigation* — *Afterimages*

Stare at the cross in **Figure 5** with one eye for 30 s, and then stare at a bright white surface for at least 30 s. The colours will reverse. The afterimage is believed to be caused by fatigue of that particular type of cone in that area of the retina. The horizontal red cones become fatigued, but the complementary green cones continue to fire. The opposite effect occurs for the vertical bar.

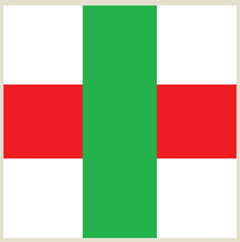


Figure 5
The red bar produces a green afterimage; the green bar produces a red afterimage.

Focusing the Image

As light enters the eye, it is first bent toward the pupil by the cornea. Light waves normally travel in straight lines and slow down when they enter more dense materials like the cornea. The slowing of light by a denser medium causes bending, which is called refraction. The cornea directs light inward toward the lens, resulting in further bending. Because the lens is thicker in the centre than at its outer edges, light is bent to a focal point. An inverted image is projected on the light-sensitive retina.

Ciliary muscles control the shape of the lens, and suspensory ligaments maintain a constant tension. When close objects are viewed, the ciliary muscle contracts, and the lens becomes thicker. The thicker lens provides additional bending of light for near vision. For objects that are farther away, relaxation of the ciliary muscles causes the lens to become thinner. The adjustment of the lens to objects near and far is referred to as **accommodation**. Objects 6 m from the viewer need no accommodation.

The importance of the accommodation reflex becomes more pronounced with age. Layers of transparent protein covering the lens increase throughout your life, making the lens harder. As the lens hardens, it loses its flexibility. By the time you reach age 40, near-point accommodation has diminished and may begin to hinder reading.

A secondary adjustment occurs during the accommodation reflex. When objects are viewed from a distance, the pupil dilates in an attempt to capture as much light as possible. When objects are viewed close up, the pupil constricts in an attempt to bring the image into sharp focus. Test this for yourself by looking at the print on this page with one eye. Move your head toward the book until the print gets very blurry. Now crook your finger until you have a small opening and look through it. Gradually make the opening smaller. The image becomes sharper. Light passes through a small opening and falls on the most sensitive part of the retina, the fovea centralis. Inuit were aware of this principle when they made eyeglasses by drilling holes in whalebone. Light passing through the narrow openings resulted in a sharper focus.

EXTENSION

Hyperpolarization

In this Audio Clip, you will hear about a mechanism called hyperpolarization, which is involved in creating a nerve impulse that plays a role in detection of light in the retina.

www.science.nelson.com GO

accommodation adjustments made by the lens and pupil of the eye for near and distant objects

EXTENSION

Visual Accommodation

Watch the eye change during accommodation in this interactive animation.

www.science.nelson.com GO

Vision Defects

Glaucoma is caused by a buildup of aqueous humour in the anterior chamber of the eye. Although a small amount of the fluid is produced each day, under normal conditions tiny ducts drain any excess. When these drainage ducts become blocked, fluid builds up in the anterior chamber. As the fluid builds up, the pressure inside the eye rises. The retinal ganglion cells slowly die from this increased pressure, which leads to vision loss.

Problems may arise with the lens. Occasionally, the lens becomes opaque and prevents some of the light from passing through. The condition is known as a **cataract**. A traditional solution to the problem has been to remove the lens and to fit the patient with strong eyeglasses.

In most people, the lens and cornea are symmetrical. Incoming light is refracted along identical angles for both the dorsal (back) and ventral (front) surfaces, forming a sharp focal point. In some individuals, however, the lens or cornea is irregularly shaped. This condition is called **astigmatism**.

glaucoma disease of the eye in which increased pressure within the eyeball causes a gradual loss of sight

cataract condition that occurs when the lens or cornea becomes opaque, preventing light from passing through

astigmatism vision defect caused by abnormal curvature of surface of the lens or cornea

mini Investigation — Testing for Astigmatism

The chart in **Figure 6** will help you determine whether you have astigmatism. Cover one eye and look at the chart. If you have cornea astigmatism, the lines along one plane will appear sharp, but those at right angles will appear fuzzy. Repeat the test with the other eye.

(a) In your own words, describe what causes astigmatism.

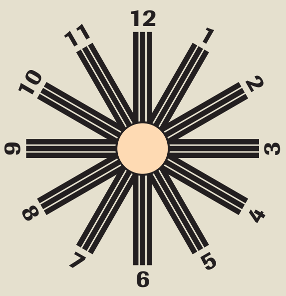


Figure 6
A test for corneal astigmatism

nearsightedness condition that occurs when the image is focused in front of the retina

farsightedness condition that occurs when the image is focused behind the retina

Two of the more common vision defects are **nearsightedness** (also known as myopia) and **farsightedness** (hyperopia). Nearsightedness occurs when the eyeball is too long. Since the lens cannot flatten enough to project the image on the retina, the distant image is instead brought into focus in front of the retina. Someone who is nearsighted is able to focus on close objects, but has difficulty seeing objects that are distant. Glasses that contain a concave lens can correct nearsightedness (**Figure 7**). Farsightedness is caused by an eyeball that is too short, causing distant images to be brought into focus behind the retina, instead of on it. A farsighted person is able to focus on distant objects, but has trouble seeing objects that are close up. Farsightedness can be corrected by glasses that have a convex lens.

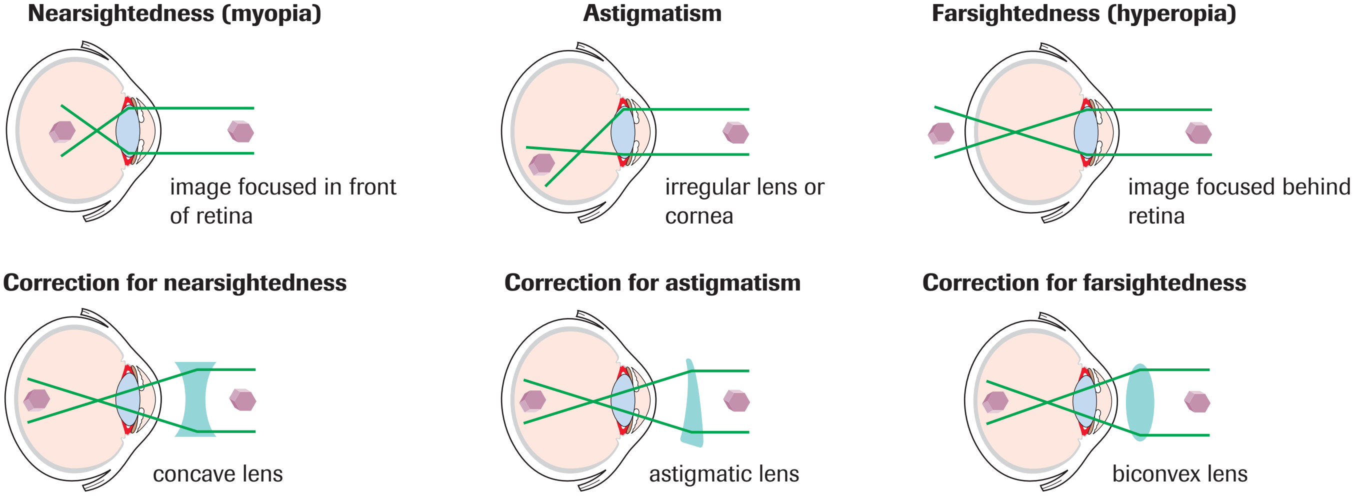


Figure 7
Visual defects can be improved with corrective lenses.

WWW **WEB Activity**

Case Study—Corneal Surgery

Surgery for treating nearsightedness was first developed in Russia in the mid-1970s by Dr. Svyatoslav Fyodorov. He was inspired by a Russian teenager whose glasses had shattered during a fight, badly cutting his cornea. Remarkably, the eye healed and the boy's myopia seemed cured. An alteration of the cornea had corrected the myopia. Dr. Fyodorov soon developed a procedure called radial keratotomy for correcting myopia.

With the development of laser surgery in the early 1980s, new, less invasive, procedures were developed, including photorefractive keratotomy (PRK) and laser in-situ keratomileusis (LASIK) (**Figure 8**). Find out how these procedures work. Also, investigate corneal ring implants and implantable contact lenses. What are the pros and cons of these two new procedures?

www.science.nelson.com GO

Figure 8
Laser eye surgery

SUMMARY The Structure of the Eye

- Images are displayed on the retina. Rods are photosensitive receptors that detect images in dull light. Cones are photosensitive receptors that distinguish colour in bright light.
- Ciliary muscles change the shape of the lens. A thicker lens permits the greater bending of light for viewing near objects, while a more flattened lens is used to view distant objects.

Section 14.2 Questions

1. Indicate the function of each of the following parts of the eye: vitreous humour, aqueous humour, cornea, pupil, iris, rods, cones, fovea centralis, and blind spot.
2. What are accommodation reflexes?
3. Why do rods not function effectively in bright light?
4. Identify the causes for each of the following eye disorders: glaucoma, cataract, astigmatism, nearsightedness, and farsightedness.
5. Illustrate how corrective lenses provide for normal vision.
6. Laser surgery can provide a cure for myopia (shortsightedness), but skeptics argue that surgery has risks and that shortsightedness can be corrected with glasses. A "halo effect" (circles of light that can distort night vision) may result from laser surgery.
   (a) Research the halo effect. How often does it occur after laser surgery?
   (b) Should people who experience the halo effect be allowed to drive at night? Why or why not?
   (c) Do you believe that surgery should be attempted? Explain your answer.
   (d) Do you think this surgery should be covered by medicare? Justify your answer.
7. Nearsightedness, or myopia, is experienced by up to about one-third of the population. Nearsighted people have difficulty reading highway signs and seeing other objects at a distance, but can see for up-close tasks such as reading.
   (a) Draw a diagram of an eye for a person with myopia.
   (b) Refractive surgery can reduce or even eliminate the need for glasses or contacts. The most common procedures are performed with a laser. The laser removes a layer of corneal tissue, which flattens the cornea and allows light rays to focus closer to or even on the retina. Refer to the Nelson website to research different laser techniques that can be used.

   www.science.nelson.com GO
8. Hawks and eagles depend upon their excellent vision for hunting. In addition to the central fovea found in most birds, hawks and eagles have a second "lateral" fovea placed to one side of the central fovea. Explain how having a lateral fovea might help hawks and eagles hunt.

14.3 Hearing and Equilibrium

DID YOU KNOW?

The Smallest Bones

The ear ossicles are the smallest bones in the body. They are fully developed at birth.

The ear (**Figure 1**) is associated with two separate functions: hearing and equilibrium. The ear can be divided into three sections for study: the outer ear, the middle ear, and the inner ear. The outer ear comprises the **pinna**, the external ear flap, which collects the sound, and the **auditory canal**, which carries sound to the eardrum. The auditory canal is lined with specialized sweat glands that produce earwax, a substance that traps foreign particles and prevents them from entering the ear.

pinna outer part of the ear that acts like a funnel, taking sound from a large area and channelling it into a small canal

auditory canal carries sound waves to the eardrum

tympanic membrane thin layer of tissue that receives sound vibrations, also known as the eardrum

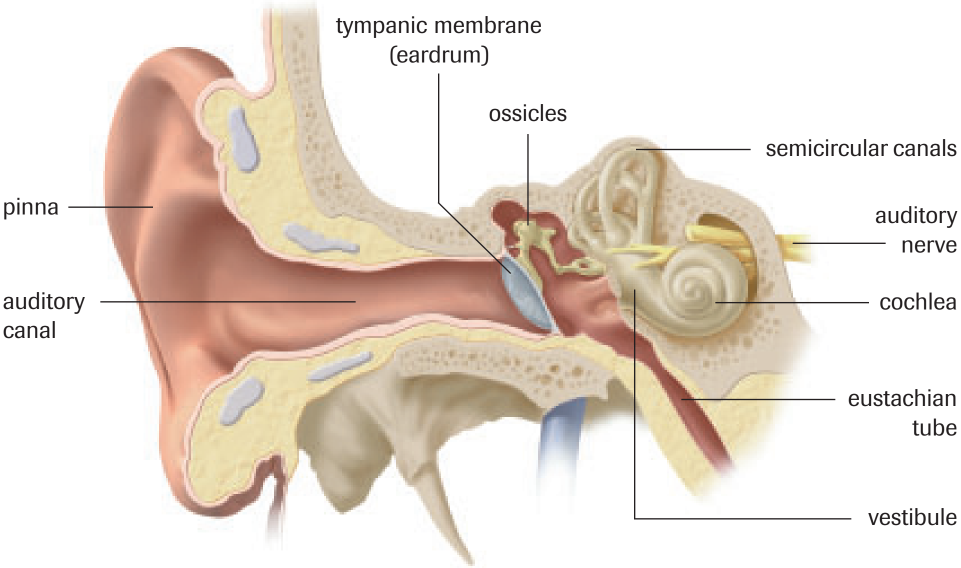


Figure 1
Anatomy of the human ear

ossicles tiny bones that amplify and carry sound in the middle ear

oval window oval-shaped hole in the vestibule of the inner ear, covered by a thin layer of tissue

eustachian tube air-filled tube of the middle ear that equalizes pressure between the external and internal ear

vestibule chamber found at the base of the semicircular canals that provides information about static equilibrium

semicircular canals fluid-filled structures within the inner ear that provide information about dynamic equilibrium

cochlea coiled structure of the inner ear that responds to various sound waves and converts them into nerve impulses

The middle ear begins at the **tympanic membrane**, and extends toward the oval and round windows. The air-filled chamber of the middle ear contains three small bones, called **ossicles**, which include the malleus (the hammer), the incus (the anvil), and the stapes (the stirrup). Sound vibrations that strike the eardrum are first concentrated within the solid malleus, and then transmitted to the incus, and finally to the stapes. The stapes strikes the membrane covering the **oval window** in the inner wall of the middle ear. Sound is amplified by concentrating the sound energy from the large tympanic membrane to the smaller oval window.

The **eustachian tube** extends from the middle ear to the mouth and the chambers of the nose. Approximately 40 mm in length and 3 mm in diameter, the eustachian tube permits the equalization of air pressure on either side of the eardrum. Have you ever noticed how your ears seem to pop when you go up in a plane? Yawning, swallowing, and chewing gum allow air to leave the middle ear through the eustachian tube. An ear infection can block the eustachian tube and create inequalities in air pressure. Discomfort, temporary deafness, and poor balance can result.

The inner ear has three distinct structures: the vestibule and the semicircular canals, which are involved with balance, and the cochlea, which is connected with hearing (**Figure 2**, next page). The **vestibule**, connected to the middle ear by the oval window, houses two small sacs, the utricle and saccule, which establish head position. There are three **semicircular canals**, arranged at different angles, and the movement of fluid in these canals helps you identify body movement. The **cochlea** is shaped like a spiralling snail's shell and contains rows of specialized hair cells that run the length of the inner canal. The hair cells respond to sound waves and convert them into nerve impulses.

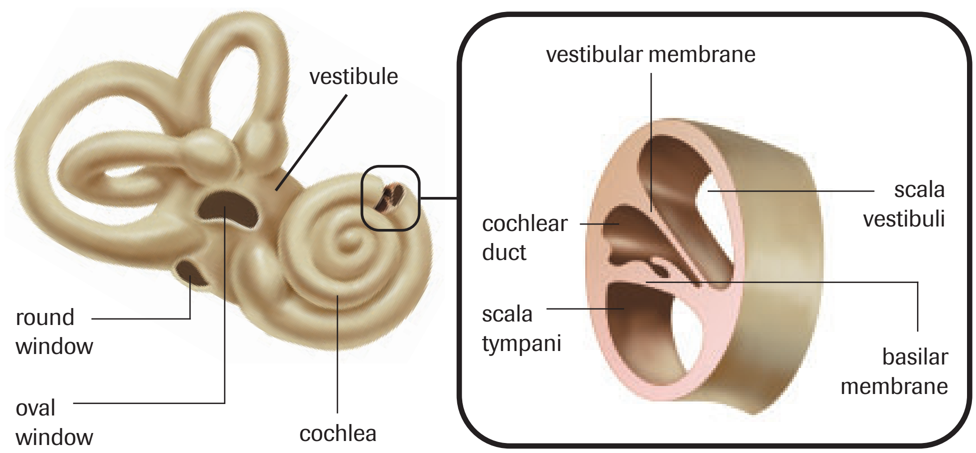


Figure 2
Sound waves are transformed into membrane vibrations in the cochlea.

Hearing and Sound

Sound is a form of energy. Like light, thermal energy, and various forms of chemical energy, sound energy must be converted into an electrical impulse before you can interpret it. The sensitivity of the ear can be illustrated by the fact that you can hear a mosquito outside your window, even though the energy reaching your ear is less than one quadrillionth of a watt. The average light in a house uses 60 W of energy.

Hearing begins when sound waves push against the eardrum, or tympanic membrane. The vibrations of the eardrum are passed on to the three bones of the middle ear: the malleus, the incus, and the stapes. Arranged in a lever system, the three bones are held together by muscles and ligaments. The bones concentrate and amplify the vibrations received from the tympanic membrane. The ossicles can triple the force of vibration from the eardrum; they move a shorter distance but exert greater force by concentrating the energy in a very small area.

Muscles that join the bones of the middle ear act as a safety net protecting the inner ear against excessive noise. Intense sound causes the tiny muscles—the smallest in your body—to contract, restricting the movement of the malleus and reducing the intensity of movement. At the same time, a second muscle contracts, pulling the stapes away from the oval window, thereby protecting the inner ear from powerful vibrations. Occasionally, the safety mechanism doesn't work quickly enough. The sudden blast from a firecracker can send the ossicles into wild vibrations before the protective reflex can be activated.

The oval window receives vibrations from the ossicles. As the oval window is pushed inward, the round window, located immediately below the oval window, moves outward. This triggers waves of fluid within the inner ear. The cochlea receives the fluid waves and converts them into electrical impulses, which you interpret as sound. The hearing apparatus within the cochlea is known as the **organ of Corti** and comprises a single inner row and three outer rows of specialized hair cells (**Figure 3**, next page), anchored to the **basilar membrane**. The hair cells respond to vibrations of the basilar membrane. Vibrations in the fluid on either side of the basilar membrane cause the membrane to move, and the hairs on the cells bend as they brush against the tectorial membrane. The movement of the hair cells, in turn, stimulates sensory nerves in the basilar membrane. Auditory information is then sent to the temporal lobe of the cerebrum via the auditory nerves.

The inner ear is able to identify both pitch and loudness because of the structure of the cochlea. Close to the oval window, the basilar membrane is narrow and stiff. Further into the cochlea, the basilar membrane widens and becomes more flexible. The narrowest area is activated by high-frequency sound waves, which contain enough energy

CAREER CONNECTION

Audiologist
Audiologists work with people who have hearing, balance, and related ear problems. Employment opportunities are expected to grow rapidly—as the population ages, more people will have hearing problems. What type of work do audiologists do? Why is the work important? What academic requirements must be met?

www.science.nelson.com GO

organ of Corti primary sound receptor in the cochlea

basilar membrane anchors the receptor hair cells in the organ of Corti

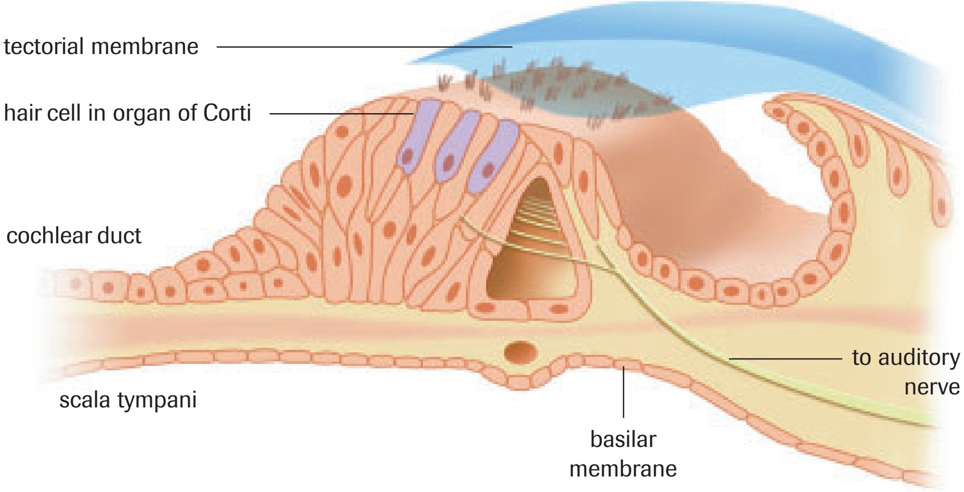


Figure 3
The organ of Corti is a ridge of cells that runs along the basilar membrane. The top of the organ of Corti meets the tectorial membrane.

to move the membrane. The high-frequency waves are transformed into basilar membrane vibrations, which, in turn, cause the hair cells to move. The hair cells trigger an action potential, which is carried to the area of the brain that registers high-pitched sounds. The high-frequency waves caused by a police siren die out quickly in the narrow, rigid part of the cochlea. However, low-frequency waves move farther along the cochlea, causing the hair cells in the wider, more elastic area to vibrate (**Figure 4**). The stimulation of nerve cells in different parts of the cochlea enables you to differentiate sounds of different pitch. Each frequency or pitch terminates in a specific part of the auditory section in the temporal lobe of the brain.

In addition to responding directly to sound energy, the basilar membrane can respond directly to mechanical stimulation. A jarring blow to the skull sets up vibrations that are passed on toward the cochlea. Aside from the sound created by the blow, the resulting mechanical vibrations of the skull can also be interpreted as sound.

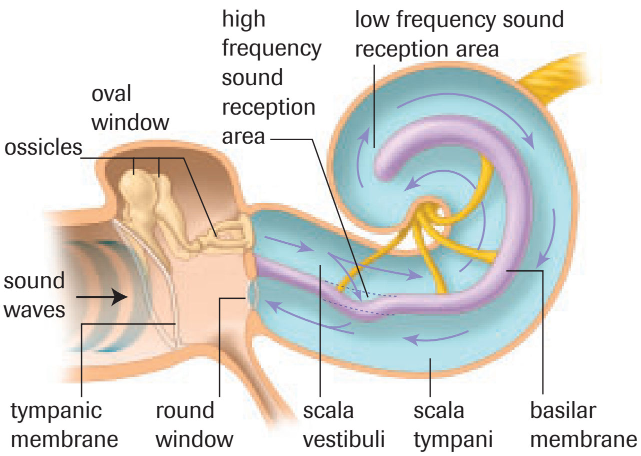


Figure 4
Here the cochlea has been uncoiled. High-frequency sounds are picked up at the base of the cochlea and low-frequency sounds are picked up towards the tip of the cochlea.

Practice

1. What function do the tympanic membrane, ossicles, and oval window serve in sound transmission?
2. Categorize the following structures of the inner ear according to whether their functions relate to balance or hearing: organ of Corti, cochlea, vestibule, saccule, ampulla, semicircular canals, oval window, and round window.

Equilibrium

Balance consists of two components: static equilibrium and dynamic equilibrium. Static equilibrium involves movement along one plane, such as horizontal or vertical. Head position is monitored by two fluid-filled sacs called the saccule and the utricle. Tiny hair cells line the saccule and utricle. Cilia from the hair cells are suspended in a gelatinous material that contains small calcium carbonate granules called **otoliths**. When the head is in the normal position, the otoliths do not move; however, when the head is bent forward, gravitational force acts on the otoliths, pulling them downward. The otoliths cause the gelatinous material to shift, and the cilia to bend (**Figure 5**). The movement of the cilia stimulates the sensory nerve, and information about head position is relayed to the cerebellum for interpretation.

otoliths tiny stones of calcium carbonate embedded in a gelatinous coating within the saccule and utricle

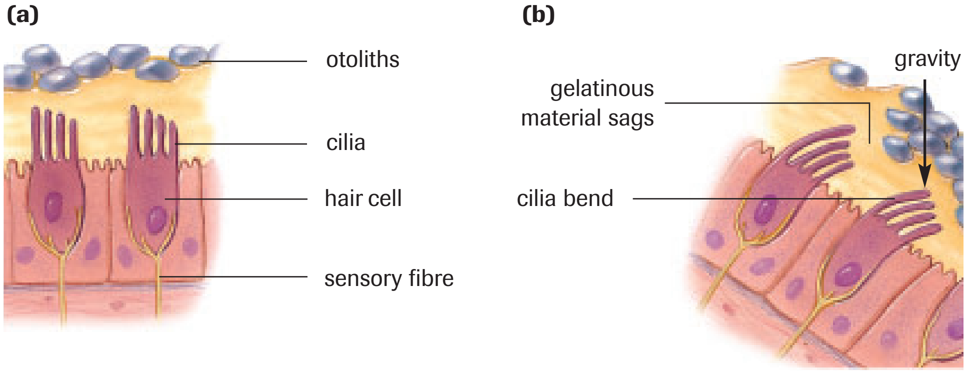


Figure 5
(a) When the head is in the erect position, the cilia from the hair cells remain erect.
(b) Movement of the head causes movement of the hair cells. Any movement of the cilia from the hair cells initiates nerve impulses.

The second aspect of balance, referred to as dynamic equilibrium, provides information during movement. While you are moving, balance is maintained by the three fluid-filled semicircular canals (**Figure 6**). Each of the canals is equipped with a pocket called an ampulla, which holds a cupula. Rotational stimuli cause the fluid in the semicircular canals to move, bending the cilia attached to hair cells in the cupulas. Once the hair cells bend, they initiate nerve impulses, which are carried to the cerebellum. It is believed that rapid continuous movement of the fluids within the semicircular canals is the cause of motion sickness.

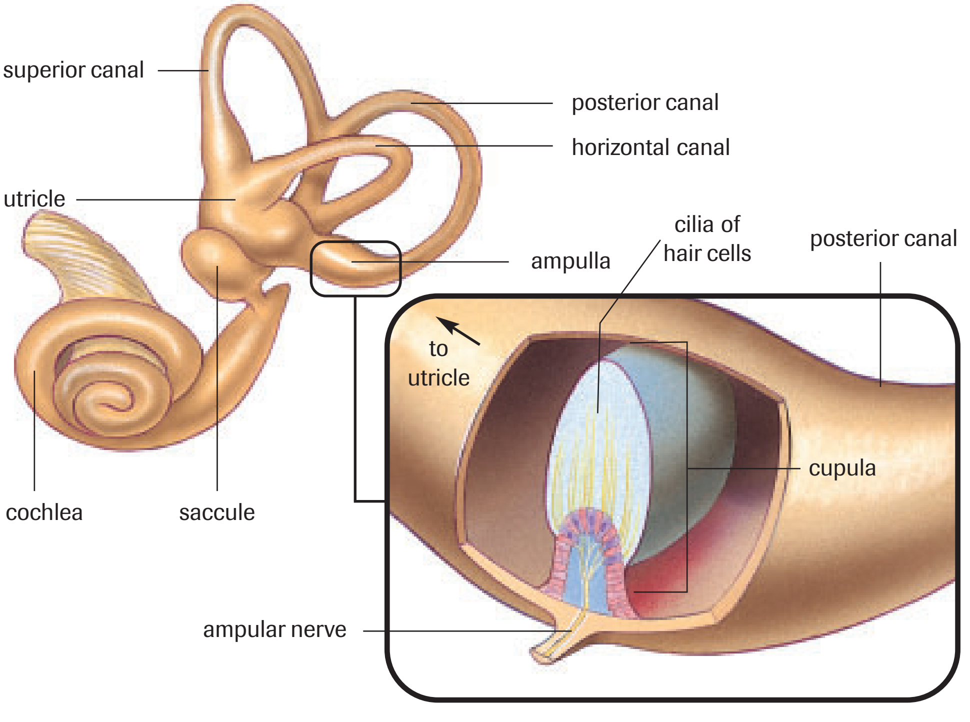


Figure 6
Three semicircular canals provide information about motion. Cilia attached to hair cells in the cupula respond to the movement of fluid in the semicircular canals.

INVESTIGATION 14.3 *Introduction*

Hearing and Equilibrium

Have you ever wondered how good your hearing actually is? Do you have trouble with motion sickness? Investigation 14.2 will help you learn more about hearing and equilibrium.

Report Checklist

- ● Purpose
- ○ Problem
- ● Hypothesis
- ● Prediction
- ● Design
- ○ Materials
- ○ Procedure
- ● Evidence
- ● Analysis
- ● Evaluation
- ○ Synthesis

To perform this investigation, turn to page 464.

Treatments for Hearing Loss

One type of hearing loss is conductive hearing loss. In this type, sound waves have trouble entering the inner ear. This can be caused by wax buildup in the outer ear, middle ear infections, or a punctured eardrum. Conductive hearing loss can often be corrected by medical or surgical procedures. Another type of hearing loss is sensorineural hearing loss, where the auditory nerve is severed or damaged or the hair cells of the cochlea are damaged or dead. It can be caused by aging, exposure to loud noises, head trauma, or genetic conditions. Often hearing loss can be a mixture of the two types.

A large variety of hearing aids exist but they all work on the same principle: they all amplify sound and transmit it to the eardrum. Hearing aids have a microphone to pick up sound, an amplifier to increase the loudness of the sound, and a speaker to transmit the sound to the eardrum. However, no amount of amplification will help if the hair cells or the auditory nerve are not working, since no vibrations are being transmitted to the brain.

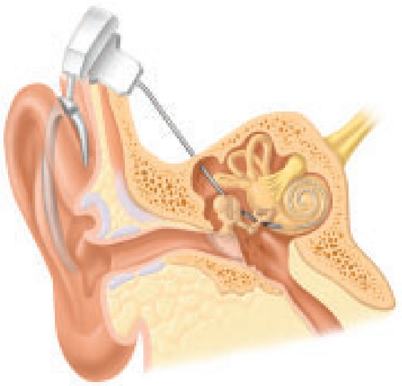


Figure 7
Unlike conventional hearing aids, cochlear implants have to be surgically implanted into the skull. Electrodes are placed in the cochlea (the grey line in the cochlea) and are connected to an external microphone placed above the ear.

Cochlear implants are devices that can restore a type of hearing to those with severe sensorineural hearing loss. A cochlear implant does not make sounds louder or clearer. The device bypasses the damaged parts of the inner ear and converts sounds into electrical impulses that are sent directly to the auditory nerve (**Figure 7**). A cochlear implant has a microphone that picks up sounds from the environment and a speech processor that selects and arranges sounds. A transmitter and a receiver/stimulator receive signals from the speech processor and convert them into electrical impulses. Electrodes then send the electrical impulses to the auditory nerves. The nerves send the coded signals to the brain, where they are interpreted as sound. Rather than restoring normal hearing by replicating the same exact sounds, the implant provides the person with sounds that enable them to interpret the environment around them. Over time the person learns to decipher what the different impulses mean and can eventually understand speech.

WWW *WEB Activity*

Simulation—Ear Structure and Function

In this simulation, you will follow sound as it travels from the outside environment through the structures of the human ear. You will look at the structures in the inner ear and how they translate the pressure changes due to sound waves into action potentials. At the end of the animation, you will complete an interactive quiz to test your understanding.

www.science.nelson.com GO

SUMMARY *Hearing and Equilibrium*

Table 1 Parts of the Ear

Structure	Function
External ear	
pinna	• outer part of the external ear amplifies sound by funnelling it from a large area into the narrower auditory canal
auditory canal	• carries sound waves to the tympanic membrane
Middle ear	
ossicles	• tiny bones that amplify and carry sound in the middle ear
tympanic membrane	• also called the eardrum, it receives sound waves
oval window	• receives sound waves from the ossicles
eustachian tube	• air-filled tube of the middle ear that equalizes pressure between the outer and middle ear
Inner ear	
vestibule	• chamber at the base of the semicircular canals that provides information concerning static equilibrium
semicircular canals	• fluid-filled structures that provide information concerning dynamic equilibrium
cochlea	• coiled tube within the inner ear that receives sound waves and converts them into nerve impulses

Section 14.3 Questions

1. Briefly outline how the external ear, middle ear, and inner ear contribute to hearing.
2. Differentiate between static and dynamic equilibrium.
3. How do the saccule and utricle provide information about head position?
4. Describe how the semicircular canals provide information about body movement.
5. A scientist replaces ear ossicles with larger, lightweight bones. Would this procedure improve hearing? Support your answer.
6. Cochlear implants are expensive. The surgery to insert cochlear implants is covered by public health-care plans, but the cochlear implant device is not. Should patients be required to pay for their own devices?
7. Should individuals who refuse to wear ear protection while working around noisy machinery be eligible for medical coverage for the cost of hearing aids? What about rock musicians or other individuals who knowingly play a part in the loss of their own hearing? Justify your position.
8. In 1660, Robert Boyle discovered that sound cannot travel in a vacuum. Research and describe his famous experiment.

   www.science.nelson.com GO

9. Research motion sickness, including its probable causes and some current solutions. You can begin your research on the Internet.

   www.science.nelson.com GO

10. Frequency is the number of vibrations produced per second and is measured in hertz. One hertz is equal to one vibration per second. Low-frequency sounds have low pitches and high-frequency sounds have high pitches. The hearing ranges for different species are listed in **Table 1**.

Table 1 Hearing Range of Various Species

Species	Approximate range (HZ)
human	64–23,000
dog	67–45,000
cat	45–64,000
horse	55–33,000
beluga whale	1000–123,000
goldfish	20–3000

(a) Which animal has the greatest hearing range?
(b) Provide a hypothesis as to why this animal has such a large range.

INVESTIGATION 14.1

Mapping Sensory Receptors

Your ability to feel objects is determined by the information that touch receptors provide your brain. Areas that are very sensitive have a great number of touch receptors. To distinguish between the touch of two pinpoints in an area, that area must contain two touch receptors. The body has different receptors for both hot and cold. Many times these receptors are very close to each other, but occasionally you may find one area that has only one of the receptors.

Report Checklist

○ Purpose	● Design	● Analysis
● Problem	○ Materials	● Evaluation
● Hypothesis	○ Procedure	● Synthesis
● Prediction	● Evidence	

Purpose

To map touch receptors in different parts of the body and to map the hot and cold receptors in a given area of the body

Materials

divider	ice
ruler	red and blue felt markers
two 50 mL beakers	paper towel
10 finishing nails	

Part 1: Touch Discrimination

Procedure

1. Using a ruler, move the points on the divider 20 mm apart and place the points on the back of a subject's hand (**Figure 1**).

Figure 1

Caution: The points on the divider are sharp. Be careful when placing the divider on skin. Do not press too hard as it may cause injury.

(a) Can the subject feel both points?

2. Have the subject look away from the area being investigated. Progressively decrease the distance between the points. Occasionally, touch with only one of the points to keep the results reliable.

(b) Record the minimum distance at which the subject can still distinguish two different points.

3. Predict which of the following areas of the body has the greatest number of touch receptors. (For example, predict minimum distance between two points that can be detected on the fingertip, and then test your prediction.)
   - palm of hand
   - fingertip
   - back of hand
   - calf
   - back of neck
   - lips

Analysis

(c) Compare your predicted and observed results.

(d) Explain why the fingertips are more sensitive than the back of the hand.

(e) Explain why the body part that you found to have the greatest number of receptors has that many receptors.

Synthesis

(f) Not every touch by an object can be felt. Design an investigation to measure the minimum pressure necessary to stimulate a touch receptor. If your lab has the necessary equipment, conduct your experiment after having your procedure approved by your teacher.

EXTENSION

Action Potentials

In this simulation, observe the relationship between different amounts of pressure and the frequency of action potentials from pressure sensors in the human hand.

www.science.nelson.com GO

INVESTIGATION 14.1 *continued*

Part 2: Temperature Receptors

Prediction

(g) Predict whether you are more sensitive to hot or cold. Do you believe you have more hot or more cold receptors?

Procedure

4. Fill a beaker with warm water and another with iced water. Place five finishing nails in each beaker. Allow the nails to sit in the cold or warm water for at least 2 min between tests.
5. Draw a square 5 cm by 5 cm on the back of a subject's hand. While the subject looks away from the test area, remove one of the nails, wipe off excess water, and lightly touch the point of the nail on the skin inside the test area. Ask the subject whether the nail is hot or cold. Then return the nail to the beaker.
6. If the subject identifies the temperature correctly, place a small dot where the nail touched the hand. Use a blue water-soluble marker for cold receptors and red water-soluble marker for heat receptors.
7. Alternate between hot and cold nails when conducting your test. (And occasionally, change the order.) Map the area within the square. Do at least 20 trials for each temperature.

Analysis

(h) Compare your observed data to the prediction that you made. What conclusions can you draw from the evidence?

Synthesis

(i) Air temperatures usually range between −30 °C and +35 °C. Body temperature is about 37 °C. Using this information, explain why temperature receptors are not evenly distributed.

INVESTIGATION 14.2

Report Checklist

○ Purpose	● Design	● Analysis
● Problem	○ Materials	○ Evaluation
○ Hypothesis	○ Procedure	○ Synthesis
○ Prediction	● Evidence	

Eye Dissection

The eyes of most mammals have very similar anatomy. By dissecting a cow eye, you can therefore better understand the structures of the human eye. Use the diagram in **Figure 1** on page 449 to help you to identify the structures. As you perform the dissection, record your observations in written notes and/or in biological drawings. Refer to Appendix A4 for a review of biological drawings.

Purpose

To observe the principal features of a mammalian eye and identify the major structures

Materials

cow eye	forceps
safety goggles	dissecting tray
lab apron	hand lens
dissecting gloves	a sheet of newspaper
scissors	

Wear safety goggles and an apron at all times. When you have finished the activity, clean your work area, wash your hands thoroughly, and dispose of all specimens and materials as instructed by your teacher.

Procedure, Evidence, and Analysis

1. Examine the outside of the eye.

(a) Identify as many structures as possible.

2. Using scissors and forceps, remove as much fat and muscle from the eye as possible.
3. Identify the sclera and the iris. With the scissors, carefully cut into the sclera, in a circle along the outside of the iris.

(b) Note and record how the sclera feels as you cut it.

4. Remove the front part of the eye.

(c) Identify and describe the aqueous humour and the vitreous humour.

5. Using forceps, remove the lens from the eye. Place the lens on the sheet of newspaper.

(d) Describe your observations.

INVESTIGATION 14.2 *continued*

6. Locate the ciliary muscles. These can be found where the lens was and appear black or very dark in colour and have ridges. The layer inside of the eye is the choroids layer.

(e) Describe the choroids layer.

7. Using forceps, remove the retina from the back of the eye.

(f) Describe the appearance of the retina, and the location of the blind spot in the retina.

INVESTIGATION 14.3

Hearing and Equilibrium

Report Checklist

● Purpose	● Design	● Analysis
○ Problem	○ Materials	● Evaluation
● Hypothesis	○ Procedure	○ Synthesis
● Prediction	● Evidence	

In this investigation, you will test the effects of environmental factors on both hearing and equilibrium. Begin by reading over the procedure, then predict what will happen in each Part. Formulate a hypothesis and explain your predictions. In Part I, gather evidence by recording the direction from which the sound seems to come and describing any changes in the intensity of the sound. In Part 2, record the direction in which the subject leans and his or her description of any sensations when standing after the chair has stopped.

Problem

What effect will environmental factors have on hearing? on equilibrium?

Materials

tuning fork
rubber hammer
metre stick
swivel chair

Procedure

Part 1: Factors That Affect Hearing

1. Strike a tuning fork with a rubber hammer and listen to the sound. Holding the tuning fork in your left hand, place the *stem* (not the prongs!) of the tuning fork on your forehead. Place the palm of your right hand over your right ear.
2. Repeat the procedure, but this time hold the tuning fork in your right hand and place your left hand over your left ear.
3. Repeat the procedure a third time, but ask your lab partner to cover both of your ears.
4. Strike the tuning fork with a rubber hammer and hold it approximately 1 m from your ear.
5. Ask your lab partner to place a metre stick gently on the bony bump immediately behind your ear. Then, ask him or her to place the stem of the tuning fork on the metre stick.

Part 2: Equilibrium

6. Ask your lab partner to sit in a swivel chair. Have your partner elevate his or her legs and begin slowly rotating the chair in a clockwise direction. After 20 rotations, have the subject stand. (Be prepared to support your partner!)
7. After 3 min, repeat the process, but rotate the swivel chair in a counterclockwise direction.
8. Ask your lab partner to tilt his or her head to the right, and begin a clockwise rotation of the swivel chair. After 20 rotations, ask the subject to hold his or her head erect and to stand up. (Again, be prepared to catch your lab partner.)

Analysis and Evaluation

(a) Provide explanations for the data collected.

(b) Using the data collected, provide evidence to suggest that sound intensity is greater in fluids than in air.

(c) Provide evidence that the fluid in the semicircular canals continues to move even after rotational stimuli cease.

(d) What causes the falling sensation produced in step 8?

(e) Describe the manner in which the semicircular canals detect changes in motion during a roller-coaster ride.

Chapter 14 SUMMARY

Outcomes

Knowledge

- describe the structure and function of the human eye (i.e., cornea, lens, sclera, choroid, retina, rods and cones, pupil, iris, and optic nerve) (14.2)
- describe the structure and function of the human ear (i.e., pinna, auditory canal, tympanum, ossicles, cochlea, organ of Corti, auditory nerve, utricle and saccule, semicircular canals, and eustachian tube) (14.3)
- explain other ways that human organisms sense their environment and spatial orientation (14.1, 14.3)

STS

- explain that scientific knowledge and theories develop through hypotheses, collection of evidence through experimentation, and provision of explanations (14.2)
- explain that the goal of technology is to provide solutions to practical problems (14.2, 14.3)

Skills

- ask questions and plan investigations by designing an experiment to investigate heat, cold, pressure, and touch receptors (14.1)
- conduct investigations and gather and record data and information by performing experiments to measure the ability to discriminate objects visually and to hear a range of sounds (14.2, 14.3) and by observing the principal features of an ear and eye and identifying the major visible structures of those organs (14.2, 14.3)
- analyze data and apply mathematical and conceptual models (all)
- work as members of a team and apply the skills and conventions of science (all)

Key Terms

14.1

sensory adaptation

14.2

sclera
cornea
aqueous humour
choroid layer
iris
retina
rods
cones
fovea centralis
rhodopsin
accommodation
glaucoma
cataract
astigmatism
nearsightedness
farsightedness

14.3

pinna
auditory canal
tympanic membrane
ossicles
oval window
eustachian tube
vestibule
semicircular canals
cochlea
organ of Corti
basilar membrane
otoliths

MAKE a summary

1. Imagine a cougar or bear suddenly walks in your path. Create a flow chart or diagram that shows how your nervous system would respond to this stressful situation. Label the diagram with as many key terms as possible.
2. Revisit your answers to the Starting Points questions at the start of the chapter. Would you answer the questions differently now? Why?

Go To www.science.nelson.com GO

The following components are available on the Nelson Web site. Follow the links for *Nelson Biology Alberta 20–30*.

- an interactive Self Quiz for Chapter 14
- additional Diploma Exam-style Review Questions
- Illustrated Glossary
- additional IB-related material

There is more information on the Web site wherever you see the Go icon in the chapter.

EXTENSION

CBC radio ONE QUIRKS & QUARKS

Blind, Naked, and Feeling No Pain

Listen to this interview with Dr. Tom Park, who has discovered that naked mole-rats don't feel pain through their skin. The animals otherwise seem to have normal sensation in their skin. Studying mole-rats may help us to better understand pain.

www.science.nelson.com GO

Chapter 14 REVIEW

Many of these questions are in the style of the Diploma Exam. You will find guidance for writing Diploma Exams in Appendix A5. Science Directing Words used in Diploma Exams are in bold type. Exam study tips and test-taking suggestions are on the Nelson Web site.

www.science.nelson.com GO

DO NOT WRITE IN THIS TEXTBOOK.

Part 1

1. The *action* and *purpose* of sensory receptors, respectively, is to
   A. increase the energy of the stimulus above the threshold level and to provide the CNS with information about the external environment only
   B. decrease the energy of the stimulus below the threshold level and to provide the CNS with information about the external environment only
   C. convert the energy of a response into an action potential and to provide the CNS with information about changes in the external environment or within the internal environment
   D. convert the energy of a stimulus into an action potential and to provide the CNS with information about changes in the external environment or within the internal environment

Use the following information to answer questions 2 and 3.

Figure 1 shows a cross section of a human eye. Structures are labelled with a letter.

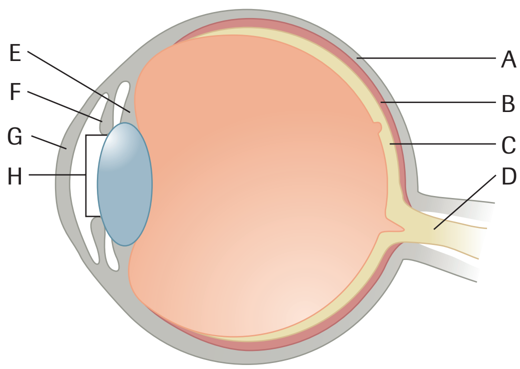


Figure 1

2. Which choice gives all three labels correctly for the given structures?
   A. A = sclera, C = retina, G = cornea
   B. B = sclera, C = retina, H = cornea
   C. C = sclera, G = retina, D = cornea
   D. F = sclera, E = retina, H = cornea

3. Identify the statement that is incorrect.
   A. Light enters through structure G on the diagram.
   B. Light enters through structure H on the diagram.
   C. Structure B on the diagram prevents light from scattering.
   D. Structure A on the diagram prevents light from scattering.

Use the following information to answer questions 4 and 5.

Figure 2 shows the internal structures of the human ear. The structures are labelled with a number.

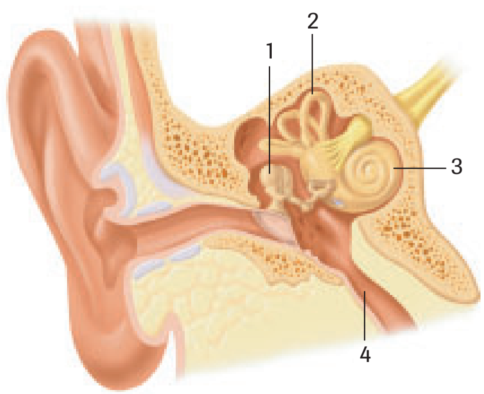


Figure 2

4. NR Match the following structures with the labels shown on **Figure 2**. (Record all four digits of your answer.)

______	______	______	______
eustacian tube	semicircular canals	ossicles	cochlea

5. The structure that is primarily responsible for maintaining dynamic equilibrium is labelled with which number?
   A. 1
   B. 2
   C. 3
   D. 4

6. A person who has colour blindness would have a gene defect expressed in this part of the eye.
   A. optic nerve
   B. vestibule
   C. cones
   D. cornea

7. NR Place the following structures in order as light passes through the eye. (Record all four digits of your answer.)
   1. aqueous humor
   2. lens
   3. cornea
   4. fovea

8. Should the curvature of the cornea along the horizontal axis of the eye be greater than the curvature along the vertical axis, the result would be
   A. glaucoma
   B. night blindness
   C. astigmatism
   D. farsightedness

9. Sensorineural deafness may be caused by
   A. the blockage of the eustachian tube
   B. damage to the basilar membrane
   C. damage to the ossicles
   D. damage to the tympanic membrane

10. NR Place the following events in the correct sequence after the initial event. (Record all four digits of your answer.)

    Initial event: Sound waves push against the eardrum or tympanic membrane.

    1. Tiny hair-like cells in the organ of Corti respond to vibrations by stimulating nerve cells in the basilar membrane.
    2. Vibrations are passed along to three bones in the middle ear: the malleus, incus, and stapes.
    3. The cochlea receives waves within the inner ear.
    4. The oval window receives vibrations from the ossicles.

Part 2

Use the following information to answer questions 11 to 14.

In an experiment, skin was exposed to different temperatures. The frequency of firing of action potentials from temperature receptors was recorded. The average frequency was then used to sketch the graph in **Figure 1**.

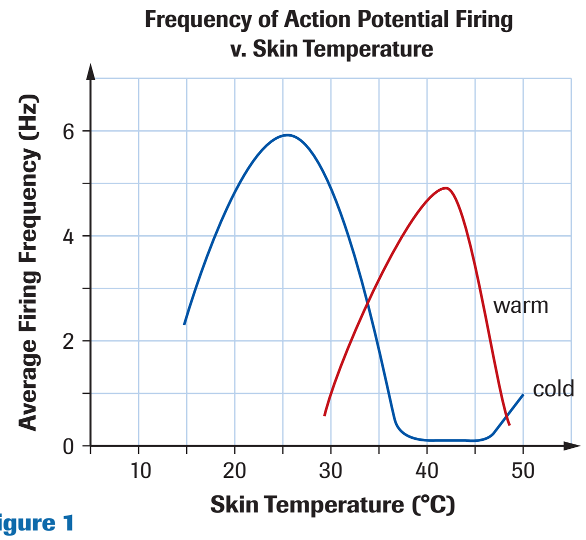


Figure 1

11. DE **Identify** the temperature at which cold temperature receptors fire most frequently.

12. DE **Identify** the temperature at which hot temperature receptors fire most frequently.

13. DE **Conclude** whether the body is more sensitive to warm or cold stimuli. **Justify** your conclusion.

14. DE **Hypothesize** why cold temperature receptors show an increased sensitivity at 50 °C.

15. The retina of a chicken is composed of many cones very close together. **Explain** the advantages and disadvantages associated with this type of eye.

16. DE Myopia is thought to be caused by a combination of genetic and environmental factors, but there are some differences in opinion. Write a unified response addressing the following aspects of myopia.
    - It was once believed that excessive reading might cause myopia. **How** might this theory be tested?
    - **How** might the link between myopia and genetics be established?

17. **Why** do people often require reading glasses after they reach the age of 40?

18. When the hearing of a rock musician was tested, the results revealed a general deterioration of hearing as well as total deafness for particular frequencies. **Why** is the loss of hearing not equal for all frequencies?

19. One theory suggests that painters use less purple and blue in their paintings as they age because layers of protein build up on the lens in their eyes. As the buildup gradually becomes thicker and more yellow, the shorter ultraviolet wavelengths from the ultraviolet end of the spectrum are filtered. **How** would you test the theory?

Use the following information to answer questions 20 to 23.

The data in **Table 1** were collected from an experiment.

Table 1 Changes in Near-point Accommodation with Age

Age	Near-point accommodation (cm)
10	7.5
20	10.2
30	11.3
40	17.2
50	56.8
60	87.3

20. DE **Identify** the problem that was being investigated in the experiment.

21. DE **Hypothesize** how the variables under investigation are related.

22. DE **Conclude** the age at which near-point accommodation is most affected.

23. DE **Explain** what causes the change in near-point accommodation. How does it affect people?